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Mapping Information Technology Adoption in Smart Cities: A Literature Review and Research Themes

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Abstract

In the growing digital era, Information Technology (IT) has created major breakthroughs in various fields, before finally playing a significant role in the Smart City (SC) concept as has been proven in many studies. Previous studies have shown that IT implementation in SC varies greatly as it has to be customized to the SC domain. Thus, it is necessary to map the feasible IT adoption for each SC domain. Here, we conducted a literature review and found several research themes of IT adoption in SC. Our findings include: (i) IT adoption in SC, and (ii) SC domains. In this study, a literature review was conducted manually on journals that examined IT adoption in SC and SC domains. The extraction and synthesis process results identified several research themes, including Geographic Information Systems, Internet of Things (IoT), Big Data Analytics, and Wireless Sensor Networks. Research questions are posed in each theme, which can be helpful to insights for future research.

Keywords: *Information Technology Adoption, Smart City, Digital Era, Literature Review, Research Themes*

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1. INTRODUCTION (UPPERCASE, 10pt, bold)

Various information technologies that have been applied to Smart City show the important role of information technology for the success of the Smart City concept. Previous studies explain that the internet of things (IoT) is the basis for the realization of the smart city concept. The use of IoT to optimize network traffic in real-time using DBN and clustering models has had a significant impact on city network management.[1]. The role of Block Chain for IoT-based Smart city provides confidence in the level of security in transaction storage, privacy of citizens from the threat of cyber crime [2]–[4]. However, IoT devices have an impact on the waste of energy in the city. So there is a need for further management of IoT devices, namely with energy management with analytical data[5]. On the other hand, it is not only about protecting citizens' privacy but also about improving the quality of citizens by adopting big data to build media literacy[6]. The use of cloud computing and big data effectively integrates information to make more comprehensive decisions on various data to achieve coordination between city operation management and industrial development. In the wireless infrastructure of smart city cities, network deployment directly affects the quality of city network services[7]. As done by [8] which designs social physical security systems in the form of complex and heterogeneous network systems used to integrate human characteristics and social life. Research on the impact of IT on all smart city sectors has been widely conducted as described earlier, and almost all smart city programs must have technology in use. However, it is important to note that researchers have used various definitions of IT adoption and Smart City for each city's problems. Therefore, a literature review is required to clearly delineate the various IT adoptions used and enable a reduction in the risk of implementation failure [9]. Where themes and future research directions can be identified. This is where the contribution of this research lies. Other research has been conducted by [10] review of ICT Governance refers to the investment and effective use of ICT to guide organizations to achieve their strategic goals. Then [11] provides direction for the use of ICT in each aspect such as e-services based on G2C, G2B, G2G. To enrich this research in addition to identifying IT adoption in smart cities, it also categorizes previous research topics into themes. So that research on IT

adoption in the context of smart cities can be clearly mapped regarding technologies that can be applied and new studies emerge based on these themes. The following will explain what IT has been implemented in SC and what SC domain mapping has currently been developed.

2. RESEARCH METHOD

In this study, the literature review methodology is based on the methodology developed [12]. Determining the study objectives, the literature collection process, research inclusions and exclusions, data extraction, and synthesis are all part of the research technique. The next sections will go over each stage in detail.

2.1 Research objective and literature search

This study identifies the IT scope employed in SC-related investigations. Furthermore, the IT adoption and SC domains will be determined. This must be done with the broad scope of SC in mind, both in terms of the concept of SC and the domains of SC. The grouping of prior investigations into topics is the end consequence of this research. This is expected to spark further investigation.

This research was conducted manually using the terms "Information Technology" and "Smart Cities" in leading online databases such as IEEE, Science Direct, ACM, Springer, Emerald, Google Scholar, AIS Electronic Library, and Wiley Online Library. These keywords were chosen to produce search results that reflect the extent of IT in South Carolina. There were a total of 2,717 journals found in the search results. The selection method yielded 48 journals, including 32 journal articles and 16 conference journals. The next section will go over the inclusion and exclusion criteria that were used.

2.2 Inclusion criteria

The journals covered in this study are all in English. Journals that discuss Smart City domains or IT adoption applied to Smart City domains (such as Smart Water, Smart Waste, and so on) are the primary criterion for journal selection. Data was taken from the 49 selected journals based on specific criteria, which would subsequently be used to develop research themes. The following information was taken from the journals: study questions posed, terminology and IT adoption utilized in SC, Smart City domains, and variables supporting the Smart City concept. Section 3 will go over the data extraction outcomes.

3. RESULT AND DISCUSSION

This subsection will discuss two main points resulting from the data extraction and synthesis. First, it will provide an explanation of the scope of information technology used in each of the Smart City domains identified in the previous research. Secondly, it will discuss the division of the research into various themes.

3.1 Information technology and Smart City Domain

Previous research has indicated diversity in the scope of Information Technology (IT) applications in the Smart City (SC) context. In this sub-section, we will explain the terms used in this context. However, before entering into further discussion, it is necessary to first explain the domain at the core of Smart City. Vito et al. [13] in their article provide a comprehensive overview of definitions, dimensions, performance, and initiatives in the context of smart cities. They highlight that the smart city concept does not only focus on Information and Communication Technology (ICT), but also pays great attention to the 'quality of people and communities'. Damiri Riciardi argues that ICT technologies can be used to monitor, assess and improve the sustainability performance of smart cities. She also proposes the Smart City Intellectual Capital (SC-IC) Framework, which is comprised of six major ideas: human, social, institutional, process, renewal, and environmental. Furthermore, he proposed five projected smart city outcomes: value, competitiveness, resilience, sustainability, and quality of life. This study demonstrates that information technology is critical to achieving the Smart City aims.

3.1.1. Information Technology Adoption in the context of Smart City

Based on several studies, Information Technology (IT) infrastructure, such as the Internet of Things (IoT), is believed to have a direct influence on Smart City (SC) implementation [14], [15]. However, most IT research in the context of Smart City regards IT as a variable or construct that can be used across various areas of Smart City. A major theme that emerges in Smart City research is the critical role of IT, and this approach is consistent with the recommendations that researchers put forward in a Smart City context. In a Smart City context, there are many ways to adopt Information Technology (IT). For example, [11] suggested using smart sensing systems to collect and manage real-time data on cyclists' health and air pollution. Wireless networks and the Internet of Things (IoT) are the core emphasis of communication technology, serving as the main infrastructure of a data-driven Smart City. In addition, the most frequently emerging components in research on the Smart City field are IT adoption such as wireless networks, big data analytics, and the Internet of Things (IoT).

1) Internet Of Things (IoT)

In many studies on the Internet of Things (IoT), there are two main references that are often mentioned, namely [6], [16], which discusses the concept of IoT. The IoT paradigm encourages the potential of IoT to support the vision of smart cities globally, so the concept of IoT is considered as one of the key elements in realizing smart cities [17]–[19]. This paradigm has

been the basis for research that identifies elements that support the idea that the Internet of Things (IoT) is an important component of smart cities. The Internet of Things concept has been used in several studies, such as [20], [21], to monitor energy consumption, forecast energy demand, and reduce energy expenditure costs. Furthermore, research [22] utilizing IoT to manage municipal waste, while [23] is used to detect fires in cities. In addition, the Internet of Things is also capable of addressing urban problems and providing rapid responses. IoT also plays a role in addressing urban problems and providing rapid response, which in turn results in improvements in the city structure [24].

2) Big Data Analytics

Some researchers have utilized Big Data technology to develop smart city concepts, as shown by [25]–[27], using Big Data by utilizing artificial intelligence to detect fires in the city early [28] utilizing Big Data to reduce the use of expensive devices such as sensors and air condition monitoring facilities in the city to address the city's pollution problem. In addition, innovation in public policy is an important component in smart city development. These innovations include plans and policies made to achieve certain goals in improving the welfare of society. With Big Data, policy definitions can be improved to achieve unprecedented levels of effectiveness in various domains, such as economic or social. However, along with that, maintaining the privacy of residents is also an important component in achieving a better quality of life in the context of smart cities. According previous studies that researchers reference, many technologies are used by researchers to solve problems uniquely. For example [23] menggunakan Internet of Things untuk mendeteksi kebakaran kota secara dini, dan [29] using big data to tackle urban fires. Various technologies can be used to solve similar problems. Therefore, it is important to identify the most appropriate technologies to implement the smart city concept and minimize the use of useless applications, as discussed in this study.

3.1.2. Smart city dimension

This section describes the domains that will be covered in this research. In general, smart city domains include smart water management, smart waste management, smart pollution control, smart energy management, smart transportation systems, and smart healthcare. The following is a further explanation:

1) Smart Water

Water is a very important resource in human life, therefore, smart water management plays a crucial role in the context of smart cities. [28] proposes the use of Internet of Things (IoT) architecture for intelligent water system management and monitoring. This architectural solution is designed to support a paradigm shift in water distribution network management by developing IoT-based Water Wise System software powered by machine learning, large-scale clustering algorithms, and deep learning, as well as integration with SCADA and GIS systems. It is hoped that this architectural solution can help overcome problems in urban water management [30]–[33].

The use of conventional methods in managing the city's current water resources can result in excessive and uncontrolled water usage. To overcome this problem [34] introduced smart meters that utilize big data technology to create an intelligent system that can manage the water cycle, from water procurement to water distribution, with the aim of improving the efficiency of city water use.

2) Smart Sewage

To better understand the role of information technology in the context of smart waste management, it is important to identify approaches that have been used to address waste management issues in many countries. The merging of information and communication technologies (ICT) and the Internet of Things (IoT) into new approaches to improving the efficiency and effectiveness of waste management systems around the world is one of the new approaches. Examples of ICT and IoT integration include the use of local sensors, data fusion, extensive data analysis, and understanding-based actions in the context of waste management. This approach enables real-time monitoring of waste management processes, which in turn enables more efficient and effective waste management, and transforms complex waste characteristics into valuable resources, materials, and energy [22], [35]–[40]. In addition, [41] has developed a cyber-physical system application with the aim of physically integrating smart waste collection systems and digital technologies to calculate, control and communicate all components of waste management, including technologies, facilities, information, sensors, actuators and networks that connect physical and digital work in waste management.

3) Smart Pollution

Sensors, mobile devices, social media, and the ubiquitous availability of accessible data have altered how data is utilized to assist policy and science. These changes open up opportunities and pose challenges for science and policymaking. To explore potential benefits and mitigate risks, it is important to address some current limitations, especially in the context of Internet of Things (IoT) deployment in smart cities and environmental monitoring. Such limitations include the development of new spatiotemporal analysis techniques, sensor interoperability, data quality, and access security [42]. In this perspective, this article presents an overview of the AirSensEUR initiative. The project's goal is to create a low-cost multi-sensor hardware and software platform that can constantly monitor air pollution at low concentration levels.

AirSensEUR is introduced with a focus on data management and offers an insight on numerous use-case scenarios where trustworthy and fast air quality data is crucial [19][43], [44].

4) Smart Energy

As social and environmental changes are significant at the global level, many cities around the world have changed their infrastructure strategies to promote sustainable mobility, develop renewable energy sources, increase renewable energy production, improve waste management, and adopt ICT infrastructure. In smart city energy systems, greater integration of heat and power sources is required, as well as a high degree of integration between households, businesses, industries, and utilities. The application of the Internet of Things (IoT) enables smart cities to efficiently control energy through comprehensive monitoring and secure communication [20]. Wireless Sensor Networks (WSNs) are a key component in the Internet of Things (IoT) and smart cities. Today, IoT relies on WSNs as an important platform for sensing and data exchange. One of the main strategies to reduce energy consumption in WSNs with highly dense sensors is to maximize the sleep period of the sensors at all times, since WSN platforms use a large amount of energy [6], [21].

5) Smart Transportation

The city's scarce resources, notably transportation, are under severe strain as the city population continues to grow [3], [42], [44], [45]. Under the new era of the Internet of Things (IoT), the dynamic improvement of transportation has become a major focus in the development of smart cities. Urban road traffic is at the core of many challenges in various fields, including traffic congestion problems and processing center system planning. One proposed solution is transportation planning based on real-time data from IoT and Geographic Information System (GIS). This data is then processed using Deep Belief Networks (DBN) and K-means algorithm to create a near-practice solution that can meet the requirements of high performance and cost efficiency [2].

6) Smart Health

The increase in the average age of the population has driven the demand for better health services. Advances in information and communication technology (ICT) have given impetus to the development of smart cities in various aspects of life, including smart health (s-Health). In this context, s-Health is used to improve healthcare by providing various services, such as patient monitoring and early diagnosis of diseases. One example is the s-Health application developed by [46], which is used to detect various diseases, including glucoma, Alzheimer's disease, bacterial sepsis, and others, by utilizing machine learning approaches. In addition [47] has proposed a patient care system framework that enables more advanced care and precise tracking of treatment locations. A combination of big data and Internet of Things (IoT) is used for data management of patients under treatment.

3. 2 Research Themes

This section outlines the identified research themes, which are primarily based on the type of information technology (IT) that can be applied in the context of smart cities. Figure 1 provides an overview of the research themes in the field of Information Technology in Smart Cities.

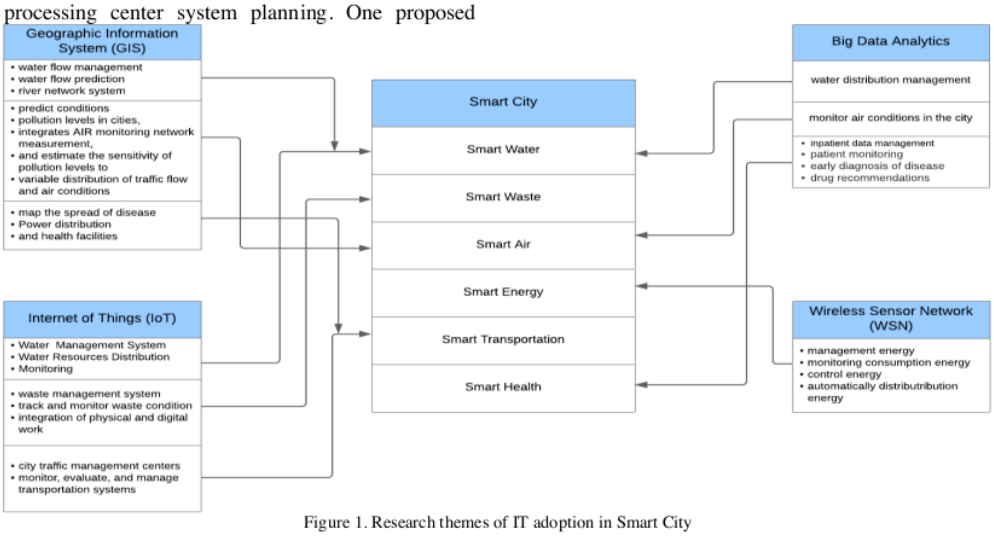

Figure 1. Research themes of IT adoption in Smart City

3.2.1. Geographical Information System (GIS)

This category or theme includes studies involving Geographic Information Systems (GIS) and how GIS plays a role in the Smart City context, for example by using imagery such as ALOS ANVIR-2, Landsat ETM, and others. This research highlights the contribution of GIS in smart city development as an important tool for monitoring city conditions and the impact of related policies[48]. This gives urban practitioners and researchers the means to utilize GIS in their efforts to improve cities. For example, [30] developed a Water Wise System application that uses GIS to manage the city's water resources, including water flow management, water flow prediction, and river network management that automatically pumps water if the river flow drops. In addition, GIS is also used to predict city air conditions in real-time, as done by [19] with water system management applications to predict a city's pollution levels and its sensitivity to traffic-induced air distribution. In addition, GIS is also used to predict the spread of disease in cities, as done by [43], which utilizes machine learning on GIS to predict the spread of diseases, distribution of health workers, and location of health facilities. The first research question (RQ1), based on past research, is to identify the sorts of urban problems that can be solved using Geographic Information System (GIS). The first study topic is, "*How can we assess the success of GIS implementation in smart cities?*"

3.2.2. Internet of Things (IoT) on Smart Cities

Some of the research that has been discussed in this category includes [2], [3], [31], [44], [47], as well as additional research conducted by [16], [24]. This research has been successful in developing the smart city concept by adopting Information Technology (IT), especially the Internet of Things (IoT), as a key technology. The outcomes of this research include city water use efficiency, city waste management, and city traffic management. However, the main focus of this research is on the technological aspect, and has not considered the significant energy consumption required by IoT devices. Therefore [20] tries to provide solutions to reduce the energy consumption of IoT devices. Based on the previous literature review, the second research question (RQ2) is: *Does the implementation of IoT in smart cities ensure the physical safety of citizens, and how does it impact the efficiency and effectiveness of smart cities?*

3.2.3. Big Data Analytics

Selain In addition to IoT as the main technology as an adoption technology for smart cities [25], [26] adopting big data analytics as the technology used to develop the smart city concept. The variable of water distribution management and automatically process is used by [28], [30], [34] to manage water sources and automate the process of water distribution in the city so as to cut unnecessary city energy. Then the variable of water control and monitoring in the city is carried out by [19] to monitor air pollution conditions in the city. This needs to be done to keep the air quality in the city healthy away from all bacteria and viruses. To maintain the health of the city [43] developed s-health applications to monitor patient early diagnosis of disease. Then [49] combines big data analytics with IoT to track the location of the referral hospital and monitor the patient's condition in real-time while on the way to the referral hospital. Based on previous research, (RQ3) *is what smart city variables can use big data?*

3.2.4. Wireless Sensor Network (WSN)

In the context of IoT adoption, IoT devices are known to have considerable energy consumption, making it important to manage energy sources in smart cities. As a solution, [21] utilizing wireless sensor networks (WSN) embedded in IoT devices to reduce the use of energy sources. In addition to minimizing energy consumption, the adoption of WSN also enables city energy consumption surveillance, energy usage monitoring, and more efficient automation in city energy management. In addition, in terms of security [23] using WSN technology in IoT devices to detect fires that can be caused by over-energization or electrical faults that might cause fires. Based on previous research, the fourth research question (RQ4) is: *Can WSN minimize energy usage in the context of smart city? And how do WSN and IoT compare in smart cities?*

4. CONCLUSION

In summary, this research uses a systematic literature review method to explore IT adoption in the context of SC and its implementation in each domain of SC. This research aims to identify technologies that can be adopted in the smart city concept so that the technology used is truly beneficial to the city. However, there are still several areas that need to be investigated in this research. Firstly, whether the technologies that have been described in this research, such as those described by [16], [25], Secondly, enabling factors, including the role of people, have not been fully identified in the context of technology adoption, as described by the researchers. Second, enabling factors, including the role of humans, have not been fully identified in the context of technology adoption, as explained by [2], [21], [25], [30]. And third, the indicators for each technology domain have not been clearly identified. All these questions will be the focus of this research as they indicate that research on information technology adoption in smart cities still has an important need. Based on the findings of the literature evaluation, this study effectively developed four relevant research questions based on the resultant research theme. This research theme is expected to address future challenges with various IT adoptions in SC and other fields. It is important to map the

appropriate technology to make IT procurement investment efficient and effective.

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Proper Noun If this word is a proper noun, you need to capitalize it.

Article Error You may need to use an article before this word. Consider using the article **the**.

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Proofread This part of the sentence contains a grammatical error or misspelled word that makes your meaning unclear.

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Article Error You may need to use an article before this word.

Prep. You may be using the wrong preposition.

Dup. You have typed two **identical words** in a row. You may need to delete one of them.

PAGE 2

Wrong Form You may have used the wrong form of this word.

Wrong Form You may have used the wrong form of this word.

Article Error You may need to use an article before this word.

S/V This subject and verb may not agree. Proofread the sentence to make sure the subject agrees with the verb.

Missing "," You may need to place a comma after this word.

Article Error You may need to use an article before this word. Consider using the article **the**.

Missing "," You may need to place a comma after this word.

Article Error You may need to remove this article.

PAGE 3

P/V You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may want to revise it using the active voice.

P/V You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may want to revise it using the active voice.

Article Error You may need to use an article before this word. Consider using the article **the**.

PAGE 4

Article Error You may need to use an article before this word.

P/V You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may want to revise it using the active voice.

Prep. You may be using the wrong preposition.

Article Error You may need to use an article before this word. Consider using the article **the**.

Article Error You may need to use an article before this word. Consider using the article **the**.

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Missing "," You may need to place a comma after this word.

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